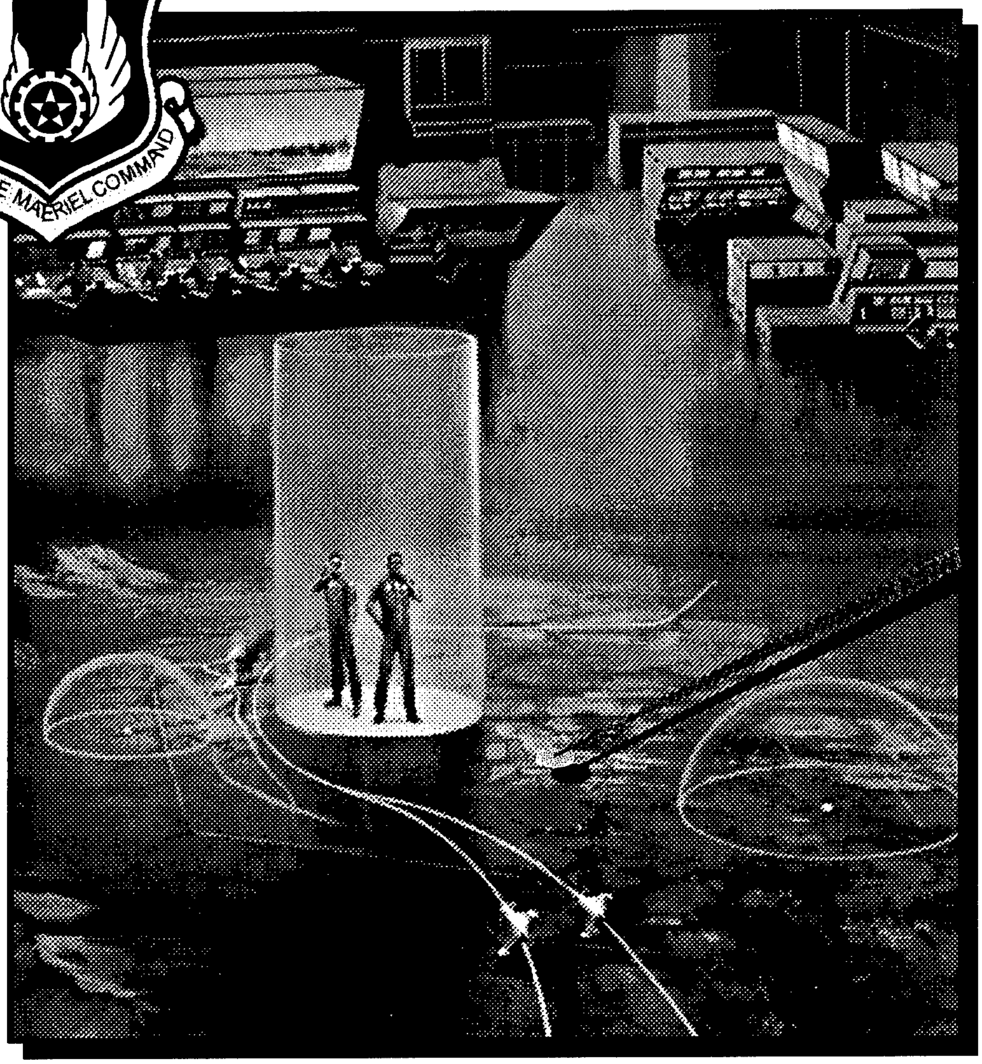
FY97
DIRECTED ENERGY TECHNOLOGY AREA PLAN



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The FY97 Directed Energy Technology Area Plan describes Phillips Laboratory's exploratory and advanced technology development strategy for high power laser weapons, high power microwave weapons, nonlinear optical beam control and imaging, and space systems venerability studies survivability techniques in hostile and natural environments.

14. SUBJECT TERMS
Directed Energy Weapons, Lasers, Nonlinear Optics, Beam Control, High resolution Imaging, Electromagnetic Hardening, Spacecraft Survivability, High Power Microwave Weapons, Chemical, Solid State, and Semiconductor Lasers, Spacecraft and Multispectral Imaging

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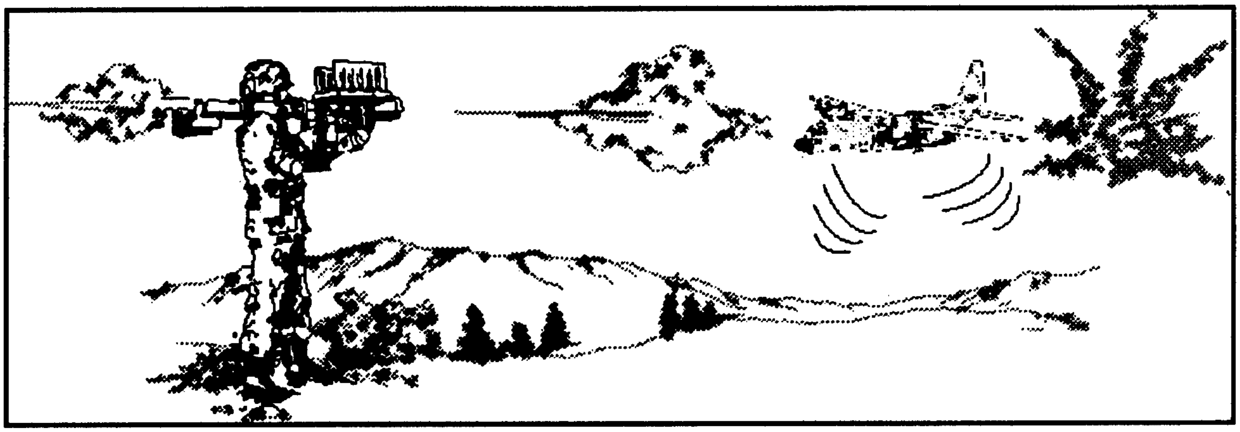

VISIONS AND OPPORTUNITIES

The Phillips Laboratory (PL) develops and transitions war-fighting technologies in three primary areas: space and missile systems, geophysics, and directed energy. This Technology Area Plan (TAP) addresses the third of these three responsibilities, Directed Energy.

This Technology Area encompasses the development, demonstration, and transition of directed energy technologies; the determination of the susceptibility of USAF systems to similar foreign threats; and the development of protection technology to enhance the survivability of USAF systems. On-going and planned R&D will lead to advanced weapon systems using high energy lasers, high power microwaves, and related capabilities such as high resolution optical imaging. Efforts in survivability assessment and protection technology involve the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, space debris, and natural and enhanced space radiation.

As a national center of excellence for directed energy, PL is well qualified to provide the technology for tomorrow's warfighters. Directed energy weapons (DEWs) offer the opportunity to leapfrog incremental advances in conventional weapons by providing revolutionary capabilities for both offense and defense. These technologies and the advanced weapon systems they make possible are a critical part of the Air Force's "Global Reach – Global Power" vision.

Within the Directed Energy Technology Area, PL develops moderate and high power laser devices; highly accurate optical acquisition, tracking, and pointing technology; high resolution optical imaging; moderate and high power electromagnetic weapons and countermeasures; and protection technologies. These application technologies are supported by on-going research in pulse power, nonlinear optics, target effects and vulnerability, survivability assessments, and systems performance and mission effectiveness analysis.

After years of investment, laser devices have reached a maturity which supports a clearly defined path to operational systems for both weapon and supporting applications. Realistic examples for weapon systems include high energy laser devices for ground-based laser antisatellite (GBL ASAT) and airborne theater missile defense (TMD) roles. Lightweight, compact, and efficient lasers at moderate power and selected wavelengths also are envisioned for a variety of applications, such as imaging, optical countermeasures, communications, illumination, target designation, and special operations.

The coming decade also will see a demonstrated capability in beam control systems. Continued progress in compensating for beam distortions due to atmospheric turbulence will provide the enabling technology for long-range laser weapon systems. The proven ability for high accuracy tracking and beam pointing give credibility to the precise application of energy at the speed of light to specific target aim points. With the combination of laser source and beam control technologies, the laser as a viable weapon system will come of age. We fully expect laser systems to proliferate in the Air Force inventory within the next ten years.

Maturing laser source and beam control technology is also the foundation for a revolution in optical imaging technology. Atmospheric compensation and illuminator laser technology, in combination with innovative image sensing and processing concepts, will greatly improve the coverage and resolution of imaging systems. Operational commands will routinely obtain high quality, timely imaging products for applications such as space object identification, long range airborne imaging of airborne and ground targets, and new technology approaches for space-based sensors. These technologies will become the eyes of the Air Force of the future.

High Power Microwaves (HPM) represent a major potential advance in Electronic Warfare technology by extending conventional RF power output several orders of magnitude. This enables the damage and disruption of a much broader range of targets and simplifies the threat-specific nature of systems. HPM can therefore not only attack multiple enemy communications and radar systems, but is also a potential generic countermeasure to a wide range of IR and RF guided weapons. Several advanced technology demonstrations of HPM weapon concepts are planned in coordination with USAF operational users. This electronic sword works both ways, however, and protecting US electronic assets is equally important. This involves not only the careful design of US HPM weapons, but also hardening US assets against potential enemy HPM and other inadvertent RF threats. PL is at the forefront in developing RF susceptibility measurement and systems hardening technologies for transition to military users and industry. Finally, PL is pursuing advanced pulse power development as a key technology for high power RF sources.

Integral to good S&T investment strategy and planning is the development of advanced technologies and tools that ensure cost effective survivability and sustainability of high-value space systems. Such is the future of the PL Space Control Technologies thrust. The Satellite Assessment Center develops and uses world-class modeling tools to complete unique survivability and vulnerability assessments for US and foreign space systems, subjected to a wide range of threat environments. Over the next few years we will fully integrate the survivability and vulnerability characteristics of additional satellites to directed energy and kinetic energy weapons into the Center's unique capabilities. Our research into RF & Laser technology for space control builds upon a broad technology base for applications. This research will provide important new options to deny the enemy's freedom to operate in space. Investigation continues into natural threats to space assets including high frequency electromagnetic energy, radiation, and space debris. In the future characterization of space debris will guide national policy on debris mitigation and protection.

PL's vision of the future in directed energy is one of providing major new military capabilities and shaping the nation's defense posture. With talented and dedicated professionals and modern research facilities, we stand ready to meet the challenge of military superiority in the next century.

RICHARD R. PAUL
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Technology Executive Officer

MICHAEL L. HEIL, Colonel, USAF
Commander
Phillips Laboratory

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INTRODUCTION

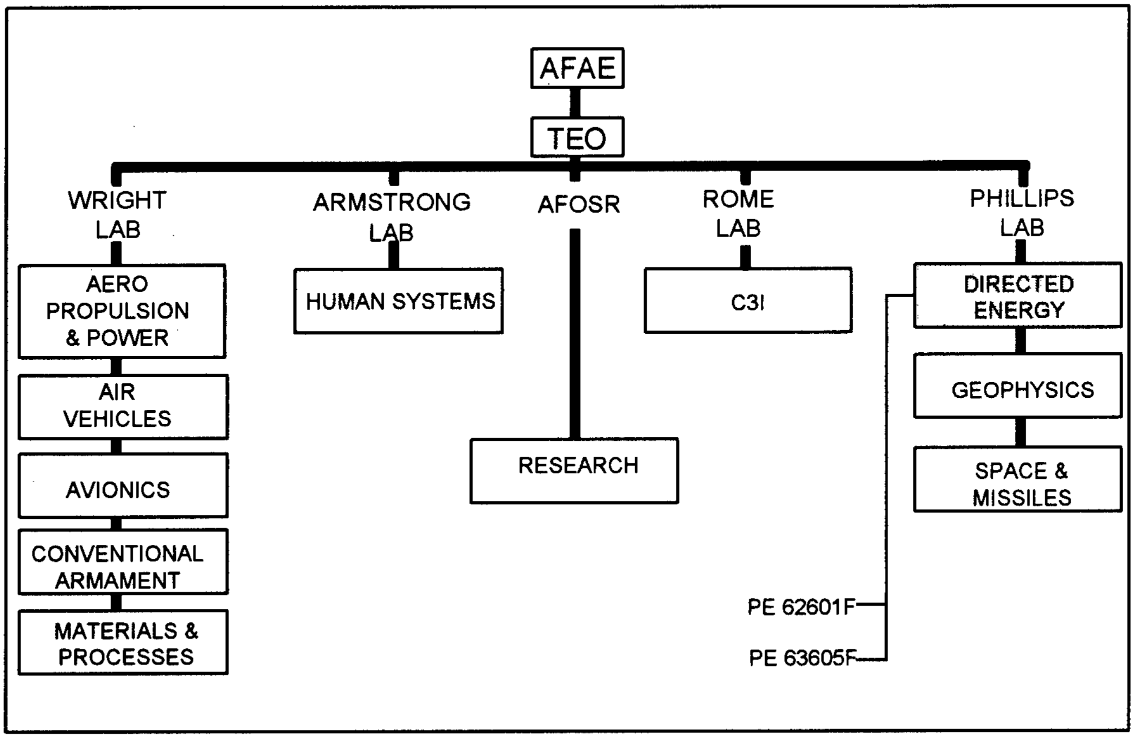

Figure 1. AF S&T Program Structure

BACKGROUND

The Directed Energy Technology Area is managed by the Commander of the Phillips Laboratory, as indicated in Figure 1. It is executed by the Advanced Weapons and Survivability and the Lasers and Imaging Directorates, with the majority of the technical activities performed at Kirtland AFB, New Mexico. This Technology Area encompasses the development, demonstration, and transition of directed energy and assessment of the survivability of USAF systems to similar foreign threats. For advanced weapon concepts, on-going and planned R&D will lead to high energy lasers, high power microwaves, high energy plasmas, and related capabilities such as high resolution optical imaging. Establishing the control and exploitation of space also requires the development of both hardening technology and the criteria for protecting USAF systems against directed energy weapons, nuclear weapons, and natural and enhanced space radiation.

Directed Energy is the one technology area where truly dramatic advances in war-fighting capabilities can occur. The ultimate goal is new weapons development and transition, enabling the Air Force to leap over the on-going evolutionary development process for conventional weapons, and thereby provide superior capabilities to support our national security.

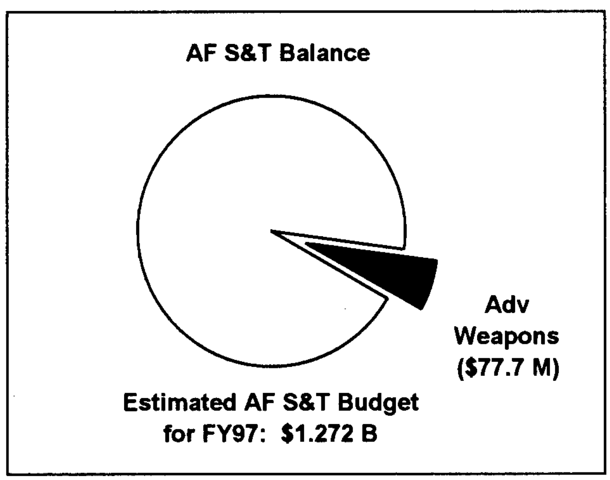

Figure 2. Directed Energy S&T Vs AF S&T

Figure 2 shows the estimated Air Force S&T budget for FY97 with the exploded segment showing those funds that are programmed for Directed Energy. The Directed Energy

Technology Area is divided into the following five major Technology Thrusts:

1. LASER TECHNOLOGY
2. BEAM CONTROL
3. IMAGING
4. RF WEAPONS
5. SPACE CONTROL TECHNOLOGIES

The division of the Directed Energy Technology Area funding by major thrust is shown in Figure 3.

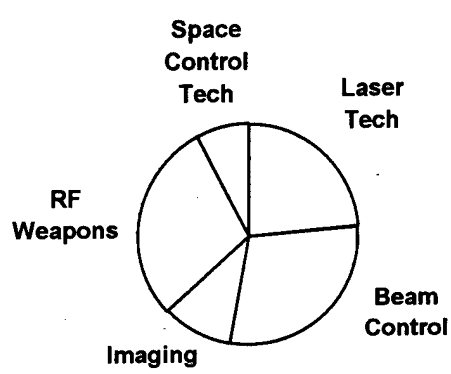

Figure 3. Major Technology Thrusts

Thrust 1: Laser Technology The overall goal of this thrust is to establish the feasibility and payoff of lasers in advanced weapon, communication, illumination, and optical counter-measure applications. Development efforts continue to address the concerns of scaling to high power, good beam quality, and high efficiency, but have recently included increased emphasis on suitability for specific classes of applications and operational environments. This has placed additional emphasis on operation in specific wavelengths bands, packaging for minimum weight and volume, and reliability and affordability in real weapon system applications.

Development and testing of the Chemical Oxygen-Iodine Laser (COIL) at small scale continues to produce significant improvements in performance and lasing efficiency. By modifying the oxygen generator to increase flow rate and reduce excited oxygen residence times, the amount of laser power per unit flow area has been improved by about 50%. Additionally, other tests have shown the feasibility of increasing the pressure in the optical cavity (thus reducing requirements for pumping) without significantly reducing laser performance and have also demonstrated the use of additional plastic components in the oxygen generator. Finally, lasing tests have begun on an advanced oxygen generator, based on uniform-droplet spray technology, with the potential to achieve further improvements in laser efficiency in a hardware configuration which is more suitable for thermal control and laser fuels recycling and regeneration. These tests establish a path for further development and scaling, to demonstrate a COIL technology base for reduced weight, volume, and fabrication costs for high power COIL devices in both ground-based and airborne applications.

Continued research into developing high power semiconductor lasers and arrays has resulted in significant achievements during the past year. Over 160 watts of quasi-coherent, continuous-wave power from an array of 64 elements was demonstrated. This device is an extremely bright source that will be useful in a number of near term applications. Research in the scaling of single devices resulted in approximately 5 watts, continuous-wave, diffraction-limited power from a single broad area laser. These achievements establish a foundation for further scaling of semiconductor laser diodes to meet application requirements involving high power, including directed energy weapons.

Great strides were also made in the investigation of semiconductor laser diodes at mid-IR wavelengths during the past year. Over 2 watts peak (380 milliwatts average) power from an optically-pumped 4 micron diode laser was demonstrated and is being transitioned to the numerous users for self protection applications. This accomplishment is an important step in producing laser sources for use in self-protection and stand-off detection applications. Investigation of nonlinear optical methods for laser wavelength agility continues to show improvement in efficiency and optical quality. A sodium wavelength source using multiple optical parametric processes that has ideal pulse format and optical quality characteristics has been demonstrated. Nonlinear optical system design models have been developed that enable the scaling of these frequency agile laser sources to at least the tens of watts level. In collaboration with the Wright Laboratories, new and exotic nonlinear optical materials are being evaluated for use in efficient moderate to high power laser sources.

The high-power semiconductor laser program has successfully demonstrated output powers in the mid-IR wavelength region sufficiently high enough for aircraft self-protection. For this reason, the program has been expanded to include packaging several 4 micron optically-pumped semiconductor lasers for delivery to the Army, Navy, and Air Force for effects testing. The inherent compactness and ruggedness of semiconductor lasers may enable them to become the lasers of choice for self-protection systems. Also, a 2.1 micron diode laser was incorporated into a prototype ground-vehicle system and field tested by the Army. In the area of laser wavelength agility using multiple nonlinear optical processes, emphasis has shifted from producing visible wavelength sources to near ultraviolet and the mid-to-far infrared. In addition, the recently developed exotic nonlinear optical materials that are produced using a periodically poled technique are being studied for possible application in extremely efficient, frequency agile, high power laser systems.

Thrust 2: Beam Control The Beam Control thrust involves the development and transition of advanced optical systems for laser propagation and high resolution imaging applications. This includes technologies for adaptive optics, highly-accurate target acquisition and tracking, precision beam pointing for aimpoint control, and high quality optical components. A major effort under this thrust is the development and demonstration of weapon-class beam control technology for both ground-based and airborne laser systems.

At Starfire Optical Range (SOR), the development of the first-generation adaptive optics for the 3.5m telescope has been completed, with installation planned to be complete by Spring 1996. Additionally, a contract was awarded in early 1995 for the development of the second-generation adaptive optics to be delivered in FY97. This telescope and the associated adaptive optics hardware are central to the planned demonstration of integrated beam control technology for ground-based laser applications.

In support of Airborne Laser (ABL) beam control technology development, a series of ground field experiments have been completed, simulating the stressing turbulence conditions and propagation environment expected for the ABL theater missile defense scenario. These initial experiments used point sources for the adaptive optics and tracking beacons and successfully demonstrated both adaptive optics compensation and closed-loop tracking performance. These experiments have been repeated with more realistic extended sources for beacons and with multiple beacon illuminators to mirage scintillation effects on the beacon.

Thrust 3: Imaging The Imaging thrust involves the development and transition of multi-spectral sensing and image processing technologies for high resolution imaging applications. This thrust takes advantage of adaptive optics and target acquisition/tracking technologies developed under the Beam Control thrust to produce a compensated, stabilized image which can then be further improved with advanced imaging sensors and post-processing of the image. Advanced concepts which can reconstruct images from interferometric or speckle data are also being pursued.

The ABLE ACE experiments to obtain critical optical measurements of high altitude atmospheric turbulence for the ABL were completed successfully in FY95. Data were taken which measured scintillation, isoplanatic patch sizes, and wavefront distortion, and correlated the measurements to turbulence strength conditions. The experiments in which instruments on the ARGUS aircraft tracked lasers projected from a companion Gulfstream aircraft were conducted under many atmospheric conditions in several different parts of the world.

Dynamic tracking tests, using real ballistic missiles in the boost phase as the targets, will be conducted at the WSMR during FY96 and FY97. These tests will demonstrate concepts for ABL active tracking, including the demonstration of initial passive acquisition of the boosting missile, hand-off to active tracking of the missile body, tracking signal-to-noise, and tracking algorithms.

There are several optical component development efforts in progress to support beam control requirements. Scaling of concepts for critical optical components, including a low-flow mirror design, cooled windows, and aperture sharing elements, was begun in FY95, with plans for delivery and laboratory evaluation in FY96/FY97.

Using speckle imaging techniques, the first satellite images have been obtained with the new SOR 3.5 meter telescope. This technique, which uses computer post-processing to improve the quality and resolution of an image, has been extended with additional tests to evaluate the synergistic effects on image quality of working with atmospheric compensation using adaptive optics. Successful results from these experiments will provide a technology for future upgrades of the imaging capabilities at operational optical sites for contribution to the space surveillance mission.

Thrust 4: RF Weapons The goal of the RF Weapons thrust is to develop and transition HPM weapons technology into the AF operational inventory and to protect US systems against potential radio frequency (RF) weapons threats. Efforts include technology development and demonstrations of advanced HPM weapons, and development and transition of RF hardening techniques to AF Product Centers and industry.

Major milestones have been attained in

demonstrating high power RF sources for a variety of wide- and narrow-band weapon applications -

- Aircraft self protection (ASP)
- Suppression of enemy air defenses (SEAD)
- Command and control warfare (C^2W/IW)
- AF Space Control

A RF effects and hardening database is being built in concert with AF Information Warfare Center, and PL has developed an automated RF effects components and C^2W subsystem testing capability to support these efforts. A full-scale mock-up of an F-16, from the cockpit forward, has also been constructed to support avionics systems HPM effects testing.

Thrust 5: Space Control Technologies The Space Control Technologies thrust assesses the vulnerability of foreign space systems in support of advanced weapon technology development programs, and defines the hostile space threat environments in which US systems will operate. The challenge is to determine the effects of directed energy, such as lasers and high power microwaves, on both foreign and US space systems and then to incorporate these findings into models and computer codes which predict space systems endurability and sustainability.

RELATIONSHIP TO OTHER TECHNOLOGY PROGRAMS

The Directed Energy technology area interacts with several other technology areas through a wide range of relationships with other agencies. These relationships range from informal coordination between technical personnel to formal program management direction. Specific relationships are established through interchanges at technical meetings, seminars and symposia. If appropriate, they are formalized through Memoranda of Agreement or Memoranda of Understanding which delineate the responsibilities for supporting directed energy technologies.

The Directed Energy technology area benefits from support for basic research provided by the Research technology area. Individual tasks investigate a range of new technology concepts within four major thrusts, with potentially high payoff for transition to longer-term development and scaling efforts. Examples include the investigation of novel, short wavelength laser concepts, adaptive optics phenomenology, basic physics issues for high performance optical coatings, aero-optics effects, advanced imaging concepts, high power RF sources, and ultra high energy pulse power.

There are many PL cooperative programs within the Air Force. In RF weapons they include Wright Labs on IR missile countermeasures, Rome Labs on Information Warfare (IW), Armstrong Laboratory on Active Denial Technology, AFFTC & AEDC on RF test facilities for aircraft & satellites, and an Air Staff sponsored program on IW protection and hardening. The Materials Directorate, WL, is also pursuing development of high power optical component technology, which is directly relevant to the goals of the Beam Control thrust.

Work in the directed energy area is coordinated through the Technology Panel for Directed Energy Weapons (TPDEW) of the Joint Director of Laboratories Committee (JDL). Representation within the TPDEW includes the Air Force, Army, and Navy, in addition to the Ballistic Missile Defense Office (BMDO), Defense Advanced Research Projects Agency (DARPA), the Department of Energy (DOE), the National Aeronautics and Space Administration (NASA), and the Federal Aviation Administration (FAA).

Among the Services, cooperation involves RF weapons coordination, which has included transition of AF HPM sources to Army programs; leverage of RF effects tests on communications gear (MICOM); missiles (MISIC & NRL) for AF programs; and cooperation on large aircraft RF effects tests and wide band source development at NSWC. The Federal Defense Laboratory Diversification Program is also the agent for transitioning RF effects developments to industry. There is an agreement among the Services that the AF will support the development of adaptive optics technology for atmospheric compensation, with the resulting technology base available to the other services to support their applications.

BMDO-funded contribution to directed energy include state-of-the-art precision pointing using an inertially stabilized reference; development and fielding of short coherence length illuminator lasers for active tracking; the integrated high altitude balloon tracking experiment; design and fabrication of uncooled high energy laser optics such as deformable mirrors and laser resonator optics.

DARPA-funded work includes the Diode-Array Pumped Kilowatt Laser (DAPKL) program. DOE contributions include work in pulse beaming technology investigations; specialized security sensor development; RAF coupling code development; and mid-IR semiconductor laser diode development. Additionally, NASA is investigating power beaming and long range laser communications, and the FAA is exploring RF threats to aircraft.

PL S&T investments are significantly enhanced by teammates in the industrial sector. There has been continuing emphasis on technologies oriented to airborne laser systems, stimulated by the establishment of the ABL program and the award of ABL Concept Definition Studies in mid-FY94. There also continues to be significant investment by industry in the area of high energy chemical lasers, advanced optical imaging, semiconductor laser diodes, HPM sources, and RF hardening. A close relationship with industry is also illustrated through a number of active Cooperative Research and Development Agreements (CRDAs) in areas such as laser development for materials processing and medical applications, optical coatings process development, HPM source development, and RF effects testing and hardening of commercial vehicles (GM), aircraft (Boeing), and computer components (Intel).

PL manages the SMC Small Business Innovative Research (SBIR) program. Planned efforts in directed energy include at least 45 efforts addressing specific technologies in DEW, imaging systems, and weapons survivability. In proposing topics for the SBIR program, one of the strong considerations has been the potential for commercialization of the potential product, as well as the innovation required for a solution. This concept maximizes the potential gain for both the small business and the government.

Interactions with international R&D programs are productive in essentially all areas of research within the Directed Energy Technology Area. The interaction ranges from the exchange of data and information in areas of common interest, through the funding support of specific research initiatives in foreign countries, to the joint support of specific research and testing initiatives both at home and abroad. A total of 10 different international agreements are involved, with an estimated dollar value exceeding $1 million.

CHANGES FROM LAST YEAR

The ABL beam control technology program emphasized tracking technology, additional tests of tracking concepts and algorithms in simulated ABL theater missile defense scenarios. Laser illumination of boosting missiles at WSMR has been successfully completed. Active Tracking experiments are planned for late FY96 and FY97.

The pace of the HPM Suppression of Enemy Air Defenses (SEAD) program has significantly accelerated with the initiation of a hardware effort to develop and field a brassboard demonstrator by FY99. HPM Command Control Warfare (CCW) has been renamed HPM C^2W/IW in recognition of its continually expanding scope and activities in support of Air Force and Joint Staff Information Warfare requirements. Overall reductions in Exploratory Development Thrust 4 funding have necessitated suspension of the HPM Counter Air (CA) program. Selected CA technologies supporting C^2W/IW and SEAD, however, are continuing under these latter programs' auspices. Finally, Enabling Technology has been descoped and combined with the RF Sources Subthrust. Emphasis in this area is now directed primarily at ultra high energy, fast switch technology in support of second generation HPM sources.

THRUST 1: LASER TECHNOLOGY

USER NEEDS

This thrust supports the following mission areas and associated technology needs or deficiencies as provided in the current Mission Area Plans (MAPs):

Air Force Space Command
- Counterspace/Space Control: counterspace (negation) capability - Antisatellite (ASAT).
- Command & Control/Force Application: no current weapon systems - high energy lasers.
- Command & Control: satellite communication crosslinks (laser).
- Space Surveillance: limited space intelligence support (SOI, MPA, imagery, status assessment).
- Lasers in space

Air Combat Command
- Theater Missile Defense: attack and kill capability - Airborne Laser (ABL).
- Counter Air: laser IR countermeasures.

Air Force Special Operations Command
- Joint Air-SOF Battlefield Interface: secure, antijam, low probability of intercept/low probability of detection (LPI/LPD) communications.
- Combat Support: enhanced medical field laser system; security police directed energy weapon (DEW) capability; reliable, pocket-size, chemical detection device; chemical standoff detection system.
- Force Application: future gunship weapons-lasers; limited IR countermeasures (IRCM); nonlethal weapons technology/area denial; enhanced target identification capability.

Air Mobility Command
- Airlift/Air Refueling: advanced IRCM.

GOALS

The overall goal of the Laser Technology thrust is to demonstrate and establish the feasibility and payoff of lasers for military applications and transition the technology to meet user needs.
Specific goals include:
- Demonstrate Chemical Oxygen-Iodine Laser (COIL) device scaling, high pressure operation, and extended run times for applicability to high power DEW systems, with emphasis on ground-based laser and ABL TMD missions.
- Demonstrate scaling, packaging, weight reduction, and gravity-independent operation technologies to allow COIL devices to be used for ABL TMD missions.
- Transition semiconductor diode laser sources, when suitable, to satellite crosslink communication developers.
- Demonstrate and transition lightweight, compact, high efficiency semiconductor diode and diode-pumped lasers to meet customer needs in the areas of communications, remote and environmental sensing, terrestrial illumination, nonlethal weapons, medical applications, countermeasures, and target illumination for active tracking..
- Develop advanced laser sources, e.g., new gas phase lasers; high repetition rate, ultra-short pulse lasers, etc., for high payoff applications where current laser source state-of-the-art fails to meet application requirements.
- Develop high power frequency agile sources in the near ultra-violet, visible and near infrared using nonlinear optical processes. Demonstrate a 10 watt class frequency agile laser system that uses multiple nonlinear optical processes.

MAJOR ACCOMPLISHMENTS

Significant progress was made in FY95/96 in the area of high power semiconductor laser arrays and single devices. Over 160 watts of continuous wave, quasi-coherent output from an array of 64 elements was achieved. This demonstrated the feasibility of getting 200 watts of coherent output power by injection locking the array with a single master oscillator by FY99. These results will provide opportunities for semiconductor lasers to meet application requirements involving high power, including long range laser communication, optical countermeasures, area denial, high power illuminators for enhanced target identification, and directed energy weapons.

Progress in the single device program has resulted in 5 watts (continuous wave), diffraction limited output from a broad area emitter. Transition of these devices will continue to provide near-term application solutions for laser communications, remote/environmental sensing, and medical applications. These high-power single devices will also provide the building blocks for incorporation in array architectures to achieve very high powers. Two new contracts were awarded in FY95 that will develop high-power, coherent, fiber-coupled lasers with a goal of 10 watts, continuous-wave, diffraction-limited output power from a single-mode optical fiber in FY99. Also, to further develop semiconductor laser

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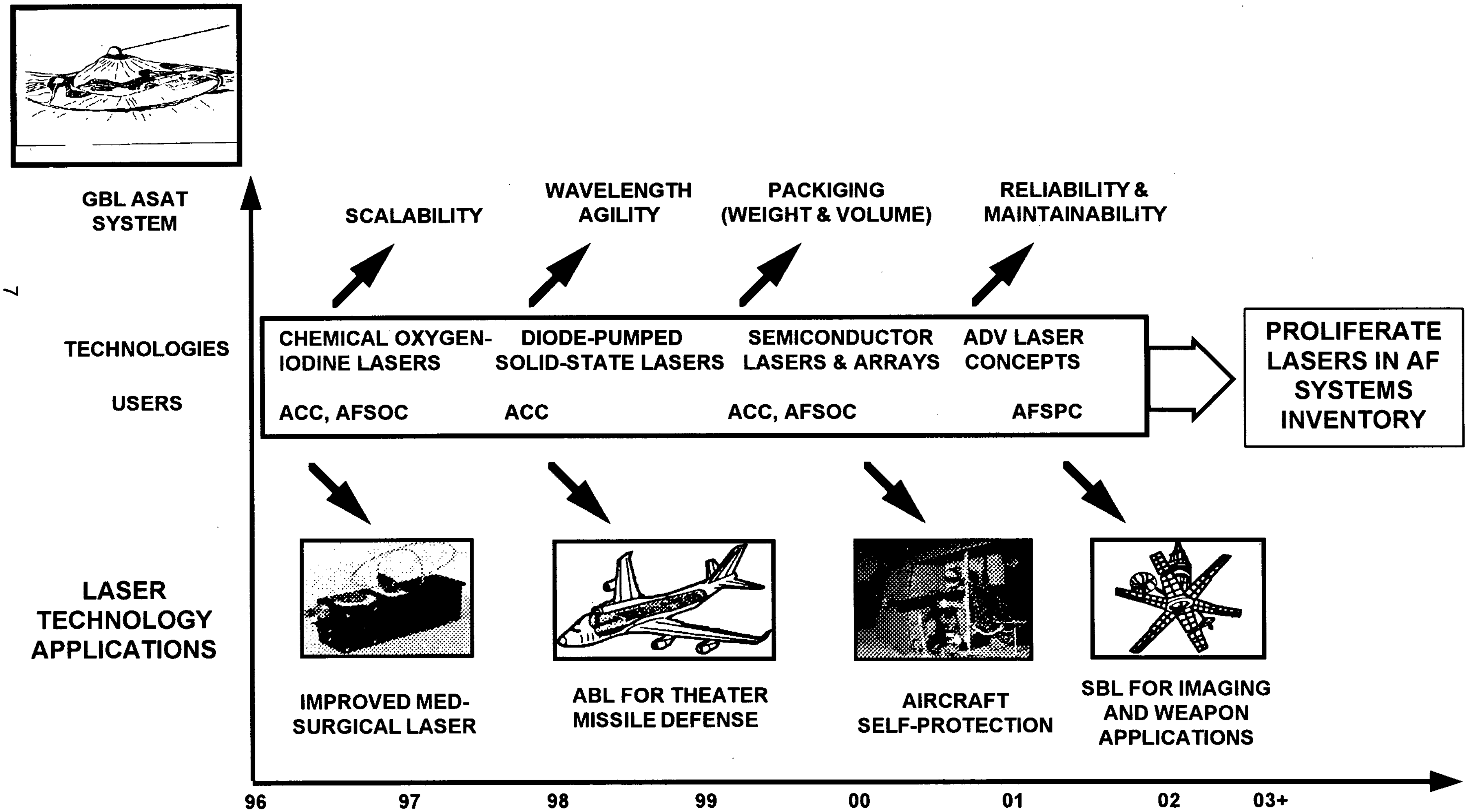
LASER TECHNOLOGY



technology, a BAA was released in FY96 for investigation of advanced concepts for improving semiconductor diode laser coherent power and beam quality.

In FY95/96, a mid-IR laser at 4 microns with an average power output of 380 mW was demonstrated. This is a significant step in the development of compact, efficient laser sources for wavelength-specific applications such as eye-safe illuminators, stand-off detection and self protection. A laser source was demonstrated that produces 1 watt of high quality light at the sodium wavelength. This source had the ideal pulse format to optimize the return from a guidestar in the mesospheric sodium layer. The source is scaleable to the power levels required for high quality space object imaging. The technical understanding of the interactions of ultra-short, infrared lasers (<100 femtosec) with infrared photosensitive semiconductor materials has been significantly increased during the last year. Emphasis was placed on understanding the behavior of InSb, InAs, and HgCdTe detector materials. Internal carrier dynamic interactions with the semiconductor materials along with measurements of the strong TeraHz radiation generated from such interactions have been characterized. Two mechanisms causing the TeraHz radiation have been identified: "Current Surge" where free photocarriers are created by the ultra-short laser pulse, which then accelerate due to the strong electric field in the depletion layer and radiate as an electric dipole. At higher fluences (>1MW/cm^2) nonlinear optical rectification becomes the radiative mechanism. Additionally, carrier dynamics of HgCdTe have been observed. This material exhibits transient behavior in the sub-100 femtosec regime which suggests that it, as well as the other two materials, may have applications in ultra-fast laser communications.

Risk reduction for a moderate-power sodium wavelength laser source has been completed, for potential application as a beacon laser for atmospheric compensation. The design uses Raman Conversion to produce the desired wavelength. The nonlinear frequency converters will be pumped by a specially designed, compact, diode-pumped solid-state laser.

CHANGES FROM LAST YEAR

Laser diode array work will be focused in FY97 on the scaling of surface emitting architectures. High power frequency agile laser source work has continued to be a high priority and should deliver a device prior to FY97. Modelocking of COIL was demonstrated in FY96. A modelocked COIL could be very useful as an illuminator for the Airborne Laser, providing the high powers required and minimizing system weight. Further experiments in this area will continue in FY97. There will be an increased emphasis on accurate modeling of COIL phenomena using the MINT 3D hydrodynamics code, accelerating its operation, and benchmarking the code using data obtained on PL and Israeli COIL devices. This modeling is critical in order to assist the Airborne Laser SPO in evaluating competing contractor laser designs. An accelerated demonstration of laser-produced plasma (Degrade/Damage-D^2) effects for IR countermeasures will be concluded in early FY97. In addition, D^2 IRCM system studies, advanced susceptibility tests, and device development will be conducted on CO overtone lasers for IRCM, IBx photodissociative lasers for space applications, and laser systems for laser communications.

MILESTONES

The development and demonstration of COIL device technology to meet the requirements of near-term HEL applications, such as GBL ASAT and ABL TMD, requires advanced oxygen generator technology to achieve high output power and long run-times. On-going development of an advanced generator will continue through FY96, with final scale-up and demonstration on a scaled in-house device in FY97. Additional efforts addressing specific ABL TMD issues include high pressure device operation and laser reactant recycling/regeneration. These efforts will be completed in FY96.

Single semiconductor laser diode technology development will continue in FY97 to obtain devices with up to 10 watts continuous output and good beam quality. These devices will be transitioned to meet near-term user needs. Semiconductor laser diode array efforts will continue to focus on surface emitting array scaling architectures throughout FY96, as well as the incorporation of advances in single diode technology. A major demonstration system is planned in FY97. This system will incorporate a number of technologies, including high power single device and coherent array technology to achieve a 100 watt laser device. In FY96, lasing at the 3 micrometers wavelength, while operating at room temperature, is anticipated. Thermal electric cooler lasing at 4 micrometers wavelength is expected in FY97. Advances in mid-IR laser source technology are now being transitioned to users for a number of applications including countermeasures.

High power diode-pumped laser efforts will continue, with a 1 kilowatt device planned for delivery by the middle of FY96. This device will support a number of applications, including high power illuminators for GBL ASAT and ABL TMD missions.

An efficient 5 watt mid-infrared source using cascaded parametric processes will be demonstrated in FY97. This system will be scaled and packaged in the outyears to meet user remote sensing and countermeasure requirements. Efforts to understand the mechanisms generating TeraHz radiation in InSb by sub-100 femtosec laser pulses have been completed. Also, the first observation of the carrier dynamics in HgCdTe with various compositions, has been accomplished. Building on these successes, extension of these studies into the 2-5 micron region will continue. Fourier Transform Spectroscopy experiments involving the TeraHz radiation are ongoing. Propagation of these ultra-short laser pulses will continue. Radiative effects experiments and investigations are scheduled to continue through FY00. Various nonlinear methods are being investigated with the goal of producing, by FY02, a high power source (1000 W) operating from the near-ultraviolet through the visible to the near-infrared wavelength region.

THRUST 2: BEAM CONTROL

USER NEEDS

Beam control technology is central to the realization of essentially all applications of laser and optical imaging systems, because the beam control system functions to deliver the beam from the laser device to the transmitting aperture, correct for optical and atmospheric-induced distortions, acquire and track the intended target, and point the beam to the designated target aim point. Combined with the appropriate laser sources or imaging sensors, this thrust supports the following user needs, as stated in current Mission Area Plans:

Air Force Space Command

- Counterspace/Space Control: counterspace (negation) capability - Antisatellite (ASAT).
- Command & Control/Force Application: no current weapon systems - high energy lasers.
- Space Surveillance: limited space intelligence support (SOI, MPA, imagery, status assessment).
- Lasers in space.

Air Combat Command

- Theater Missile Defense: attack and kill capability - Airborne Laser (ABL).

GOALS

The overall goal of the Beam Control thrust is to develop and transition advanced optical systems and technologies for both laser propagation and high resolution imaging applications. This includes efforts to:

- Establish the technology base for atmospheric compensation for applications such as GBL ASAT, ABL TMD, and imaging for incorporation into systems in the late 90's and for planned improvements in the 2002 time frame.
- Develop and demonstrate critical optical acquisition, tracking, and pointing technology for high energy laser systems to stabilize and point the beam to a selected aimpoint and to stabilize the image plane for optical imaging applications such as space object identification.
- Develop and demonstrate key high energy laser optical component technologies to enable advanced weapon applications.
- Develop and validate the modeling and simulation tools needed for accurate performance and mission effectiveness assessments.

MAJOR ACCOMPLISHMENTS

On-going field experiments at Starfire Optical Range (SOR) have continued to evaluate adaptive optics and tracking hardware in a field environment and to develop and upgrade the hardware for future, more capable testing and demonstrations. In late FY95, a field test series called the Point-Ahead Compensation Experiment (PACE) was performed on the 1.5 meter telescope, using binary stars to measure and demonstrate compensation for tilt anisoplanatism, a significant technology issue for GBL systems. Tilt anisoplanatism is a degrading effect which is introduced because of the point-ahead nature of a satellite engagement. Because the out-going laser beam must be aimed ahead of the apparent position of the satellite, the track jitter sensed by a satellite tracking system is not in exactly the right direction. The error introduced by improperly sensing the tilt component of atmospheric turbulence distortions is referred to as tilt anisoplanatism. Initial PACE experimental results indicate that compensation should be possible, with demonstration of compensation planned for the spring of FY97.

In early FY96 active (laser illuminated) tracking of retroreflector-equipped satellites was demonstrated along with compensated imaging. This is a significant step toward a 24-hour tracking capability. More demanding active tracking experiments will be done in late FY96.

With the activation of the new SOR 3.5m telescope and facility in FY94, efforts have concentrated on the development of the associated adaptive optics. The first-generation adaptive optics system is completed. Installation of the new adaptive optics system will be completed in the Spring 1997, followed immediately by compensated imaging experiments using astronomical objects. No laser beams will be involved in these initial experiments. This system uses a total of 941 subapertures, which is scaled from the 241 subaperture system currently in use on the 1.5 meter telescope. The contract for the second-generation adaptive optics system was awarded to Hughes Danbury Optical Systems in early FY95, with hardware delivery planned for FY97.

The first series of ground propagation experiments in support of ABL technology requirements were completed in an

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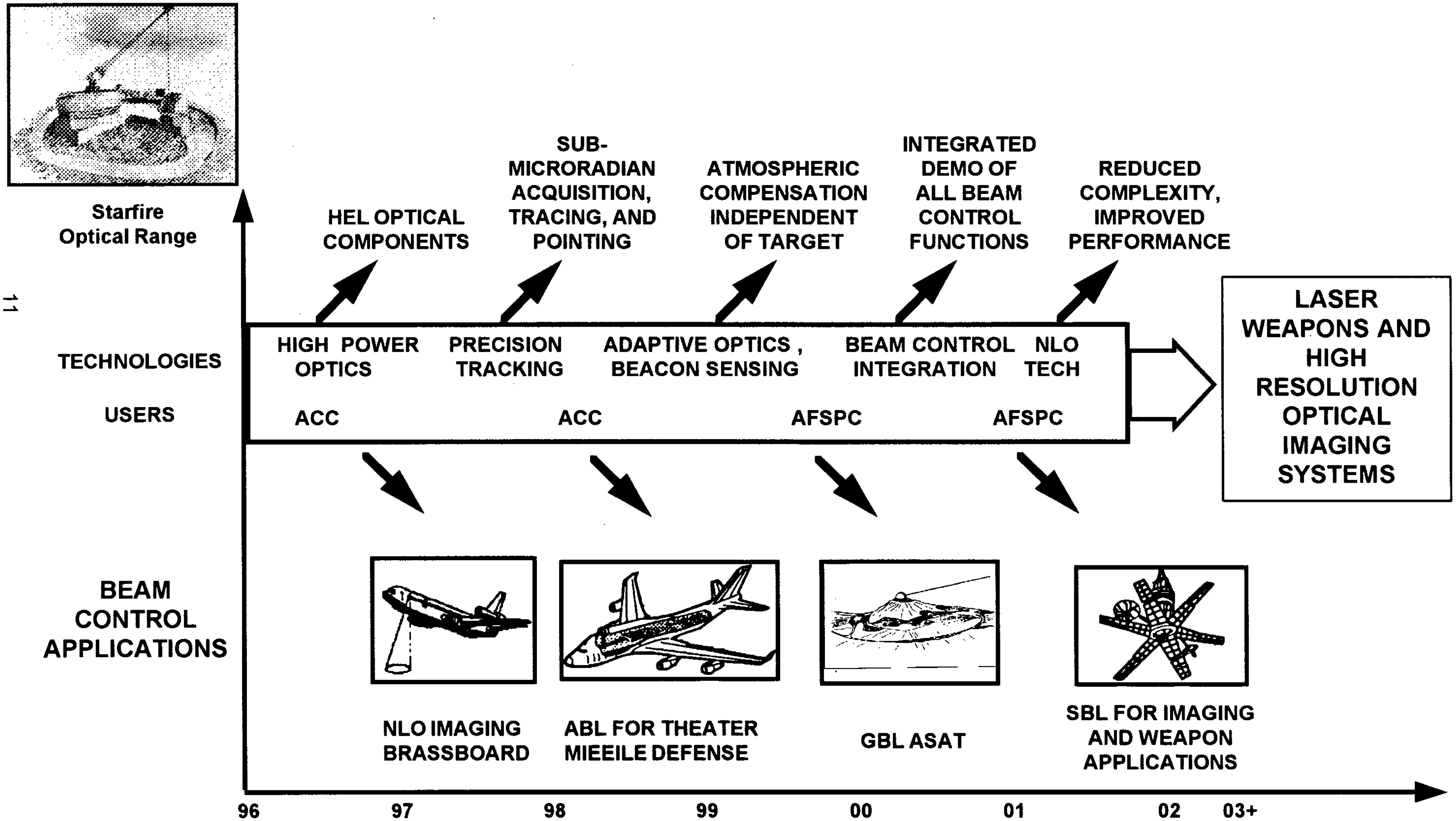
BEAM CONTROL



environment which simulated the stressing turbulence conditions expected in the ABL TMD scenario. These experiments demonstrated adaptive optics compensation and closed-loop tracking performance using point sources for the adaptive optics and tracking beacons.

The ground experiments were followed by two airborne atmospheric measurement experiments and more realistic ground experiments using extended targets. The first flight experiments, ABLE X, measured scintillation over ABL type projection paths and used the data to determine that adaptive optics corrections could restore the beam to acceptable performance. The second flight test, ABLE ACE, greatly increased confidence in the performance projections for the Airborne Laser in the Theater Missile Defense Mission. The preparation for these experiments was, in itself, a major accomplishment, as it involved the development and integration into the aircraft of complex laser and optical receiver systems capable of making the required high-resolution measurements of atmospheric turbulence over several hundred-kilometer propagation paths. The ABLE ACE missions included 28 flights which took measurements over the US, Japan, and South Korea. The final report will be complete in FY96 and indicates that, in general, the Kolmogorov modeling techniques apply to high altitude horizontal path propagation. The ABLE ACE experiment successfully anchored propagation codes for the ABL; it did not gather a worldwide data base to be used for mission planning.

Ground tests over a scaled range have been very productive in investigating extended target effects. Tests with passive extended targets showed little performance degradation in comparison to point source targets. To smooth scintillation effects when illuminating targets, a multiple beam illuminator was tested showing significant improvement in reducing intensity variations on the illuminated target. Active tracking over a range scaled to ABL conditions has been successfully demonstrated. Active track algorithms are being tested to evaluate their performance under turbulent conditions. The one draw back to the ground range is that the target is static. To investigate dynamic target effects a series of tracking tests are planned for the later part of FY96. A complete active illumination, active track, and HEL surrogate scoring system has been installed on the SLBD at the HELSTF. Active illumination tests on TMD type missiles have been successful. Active tracking tests are scheduled for the 3rd & 4th quarter of FY96 with scoring tests planned for late FY96 & 1st quarter of FY97.

A new effort to gather worldwide atmospheric data is being planned in FY96. This effort will be in conjunction with the Geophysics Directorate. Initial flight tests will evaluate the ability to correlate balloon data, radar data, and aircraft carried temperature probe data. Based on these results a measurement effort will be planned at many locations around the world.

CHANGES FROM LAST YEAR

The ABL beam control technology program has been enhanced to add additional tests of tracking concepts and algorithms in a dynamic tracking environment which simulates that of the ABL TMD scenario. These tests are planned to use existing beam control system hardware -- the Navy's Sea Lite Beam Director (SLBD), located at White Sands Missile Range (WSMR), in FY96. The SLBD tracking experiments will capitalize on a large number of ballistic missile launches planned by the Army at WSMR in 1996 and 1997 so that active tracking performance data can be obtained against thrusting boosters.

MILESTONES

Many activities in this thrust converge to full-scale demonstrations of GBL beam control technologies in FY00. These demonstrations will be conducted on the new 3.5m telescope, which was activated at SOR in early FY94.

The installation of the first generation adaptive optics system for the 3.5m telescope is planned to be completed in FY96. The first demonstration of star-loop atmospheric compensation performance is planned for the last half of FY96. Key FY96 experiments will include compensated imaging of both astronomical objects and LEO satellites, followed in late FY96 by compensated low-power laser propagation demonstrations. Finally, a second generation large scale adaptive optics system will be integrated in FY97, enabling full-scale atmospheric compensation for both imaging and laser projection.

High bandwidth, passive tracking of satellites was initially demonstrated on the 1.5m telescope at SOR in early FY94. In FY96 a near-infrared illuminator laser device will be installed at SOR to support high accuracy active tracking field experiments. Work in parallel on tracker upgrades and aim point designation and control algorithms will be incorporated, leading to full-scale, low power field tests of acquisition, tracking, and pointing technology appropriate for GBL applications in FY98-9. In this case, the performance metrics are the residual tracking error and the beam pointing accuracy which can be achieved against realistic satellite targets.

The final demonstrations for GBL beam control will emphasize integrated performance of the overall beam control system, including all of the functions necessary for a satellite engagement (acquisition, tracking, pointing, and atmospheric compensation). The goal is to demonstrate integrated performance which meets the requirements for a full-scale GBL system, thereby establishing the maturity of beam control technology for these applications. These integrated demonstrations will be completed in FY00.

To address ABL beam control technology requirements, a significant milestone was the completion of the atmospheric measurements program, which obtained optical sensor measurements of turbulence statistics along the high altitude, horizontal propagation path which characterizes the TMD scenario. These tests and the associated data analysis, begun in FY95, were completed in FY96. The metric is the completeness of the turbulence characterization data, as a critical input to the ABL system concept definition studies.

Ground testing will be completed in FY96 to evaluate both tracking algorithms and compensation using extended targets and active illumination. The effects on both systems during compensated tracking tests will be demonstrated in FY97.

Dynamic tracking tests, using real ballistic missiles in the boost phase as the targets, will be conducted at WSMR during FY96 and FY97. These tests will demonstrate concepts for ABL active tracking, including the demonstration of initial passive acquisition of the boosting missile, hand-off to active tracking of the missile body, tracking signal-to-noise, and tracking algorithms.

THRUST 3: IMAGING

USER NEEDS

This thrust supports the following mission areas and associated technology needs or deficiencies, as provided in the current Mission Area Plans (MAPs), through the development of advanced imaging and remote sensing techniques. Involved are passive and active (laser illumination of targets) methods to improve the resolution, extend the time availability, and reduce turn-around time for space surveillance data. Conventional and unconventional methods are being developed to increase the information obtainable by the optical observation system and to increase the range from low earth orbit (LEO) to geosynchronous (GEO) altitudes. Additional efforts address the improvement of airborne and space-based imaging systems.

<u>Air Force Space Command</u>

- Space Surveillance: Inadequate continuous near Earth coverage; limited coverage (multi-phenomenology); limited space intelligence support (SOI, MPA, imagery, status assessments).
- Command and Control: Surveillance coverage; deep space surveillance.

<u>Air Force Special Operations Command</u>

- Joint Air-SOF Battlefield Interface: No real/near time information from National Systems.
- Force Application: No real time information for target study; no en-route real time information; enhance target identification capability.
- Psychological Operation: No real/near time information from National Systems.

<u>Counterproliferation Users</u>

- Includes Air Combat Command, Defense Intelligence Agency, and the CINCs.
- Long Range (>100km) detection & identification of development, production, and test of weapons of mass destruction.
- Long range detection and characterization of battlefield use of weapons of mass destruction.
- Detection and identification of illicit drug production.
- Battle Damage Assessment: Assess damage & need for follow-up strikes against underground storage facilities for weapons of mass destruction.

GOALS

The overall goals of the Imaging thrust are to develop and transition advanced optical systems and multi-spectral sensing technologies for tactical and/or strategic applications to meet user needs in the areas of quality optical imagery and remote sensing. Specific goals include:

- Develop active imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEO objects.
- Develop technologies for compensated range, lightweight space optics, scene based wave front sensing, electro-optical adaptive optics and on-board image processing.
- Develop passive imaging techniques to obtain images of LEO objects, and extend these technologies to reach deep space or GEOS objects.
- Develop advanced electro-optical devices to support other Air Force missions, including long range laser target designators, optical reconnaissance and surveillance of chemical and biological weapons in production or in use on the battlefield.
- Develop nonlinear optical systems to automatically correct for dynamic optical errors introduced by the atmosphere, and to correct for static errors to very large diameter, lightweight, deployable primary mirrors on imaging satellites.
- Provide information to the users.

MAJOR ACCOMPLISHMENTS

Several major accomplishments during the past year have contributed significantly toward the achievement of technical goals and addressing stated user needs and deficiencies. These accomplishments range from the successful completion of laboratory proof-of-principle experiments to the demonstration of techniques in realistic field experiments. First, in the area of passive imaging, daytime satellite imaging capability was successfully transitioned to the Maui Space Surveillance Site (MSSS) 1.6 meter telescope. Sensors and algorithms now produce near-diffraction limited performance without adaptive optics. In addition, the first satellite images using deconvolution algorithms on passive speckle data were obtained at the Starfire Optical Range (SOR), demonstrating a prototype daytime adaptive optics system. This system improved the imagery for the precompensated configuration on

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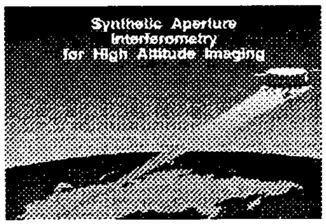
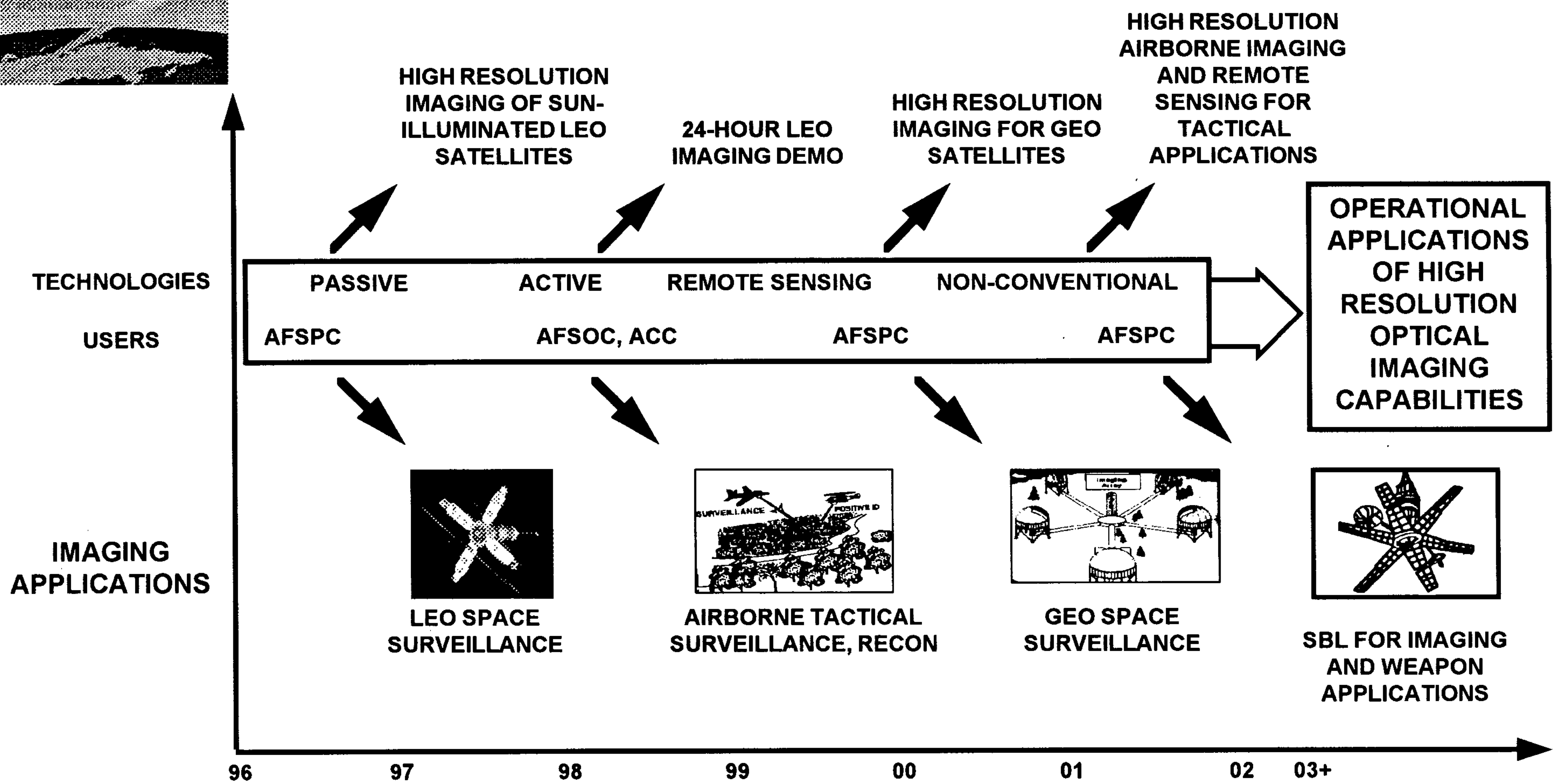
IMAGING TECHNOLOGY





the SOR 3.5 meter telescope, and will be transitioned to MSSS in FY97.

Secondly, in the area of active imaging, the iodine laser-based floodbeam active illumination demonstrator achieved first light; full satellite polarization data is expected by 1Q FY97. In another active illumination program, the HI-CLASS laser radar also achieved first light with returns from a GEOS-C satellite. Testing will continue through FY97, with the addition of another amplifier to boost output energy for space debris detection.

The third major accomplishment last year involved work in remote sensing. The Argus C-135 aircraft successfully completed periodic depot maintenance and several checkout/training flights. A full-up light detection and ranging system (lidar) for chemical agent detection will be installed and demonstrated by 1Q FY97. By completing full analysis of the 21km slant path lidar data from the Maui tests, a solid foundation for the simulation of the Airborne sensor configuration now exists.

Finally, there were several related accomplishments in support of counterproliferation efforts. PL support to several Defense Nuclear Agency (DNA) underground tests was an outstanding success. Long wave infrared hyperspectral data from the Dipole Pride tests provided critical data for redesign of the LANTIRN pod to improve battlefield damage assessment on underground facilities. Hyperspectral and lidar systems employed at White Sands Missile Range verified performance of the DNA prediction model currently used in operational theaters. As a result, DNA promised continued funding for data collection on underground facility destruction tests scheduled throughout the fiscal year.

CHANGES FROM LAST YEAR

Progress on active imaging system development and GEO fingerprinting techniques has increased AFSPC interest in space object identification and health and status of deep space objects. Preliminary tests of the laser radar space surveillance system on Maui has increased hope for a space debris detection system. Limited funds for active imaging programs has resulted in stretching the programs into FY97. Activities at the Maui High Performance Computing Center have remained about the same, decreasing hope that the center would be self-sufficient in FY97. However, U.S. Pacific Command and AFSPC have both increased the level of processing on the supercomputer. AFSPC has continued progress on transitioning the Maui Space Surveillance Site to total operational control and has officially accepted the site as an operational entity. The Deputy Assistant to the Secretary of Defense for Counterproliferation has recognized the Remote Optical Sensor program as part of the overall counterproliferation effort and provided funds for initial flight tests. Space Warfare Center (SWC) has embraced the Spectral Sensing Support Program and provided funds for assessing military utility of space-based hyperspectral systems. Initial data has been collected from ground and air based sensors. The key to this program is leveraging NASA space launches over the next 9 months. Additionally, SWC has outfitted Argus with a Talon Shield Tactical Terminal. This is the first time a moving platform will be able to receive and relay critical missile launch and position data.

MILESTONES

A passive technique, compensated daylight imaging, builds upon the results of field tests at Starfire Optical Range and on improved image processing algorithms, and will be used to demonstrate imaging of ultra-dim objects in FY97 at MSSS. By mid-late FY97, the upgraded Observatory Control System will be completed and transitioned to AFSPC, allowing for improved operation at the site. Continuing developments in sensor and adaptive optics systems will also provide the technology for an improved operational capability at the Advanced Electro-Optical Sensor (AEOS). AEOS is the new 3.67 meter telescope system which will be in place by 3Q FY97. The system will be completely operational in FY99 after delivery and installation of the required sensors.

Another effort, funded through a Congressionally-directed initiative, is the development of an Active Imaging Testbed. With continued funding support, the completion of illuminator laser development, the integration of optical receiver hardware, and the demonstration of a limited active imaging capability is planned for the end of FY97. Follow-on experiments will refine LEO imaging techniques. Subsequent active imaging work will extend the capability to GEO targets, with anticipated start of tests during FY00.

A full capability Hi-CLASS laser radar system is expected to be on line at MSSS during FY97. This system will be used to demonstrate Doppler imaging of LEO satellites and evaluate the potential for use out to GEO satellite altitudes.

Airborne hyperspectral measurements and LIDAR demonstrations planned for FY97 will support the development and demonstration of an airborne testbed for active remote sensing for reconnaissance and surveillance of chemical weapons in production or use on the battlefield.

A non-conventional imaging method intended for ground- and space-based applications utilizes nonlinear optics to remove atmospheric and large optic figure errors from a signal. To evaluate this concept, the All-Optical Imaging Brassboard (AOIB) will be integrated into the SOR 1.5m telescope during FY96. System concepts for ultra-high resolution satellite imaging will be tested in the laboratory during FY96, and field tested during FY97.

THRUST 4: RF WEAPONS

USER NEEDS

ACC, AMC, and AFSOC have mission requirements for RF weapons in Mission Area Plans and Roadmaps. Needs have been examined by the Product Centers' TPIPTs, and documented in their TIRRs. The following summarizes user needs for RF Weapons:

- Counter Surface-to-Air & Air-to-Air Missiles
- Large Aircraft IR Countermeasures
- Suppression of Enemy Air Defenses
- Air Interdiction of C^4I Defenses
- Degrade Enemy Air Control
- Degrade Enemy Military Base Operation
- Reduce Enemy Sortie Generation
- Hardened Target Weapons
- Agent Defeat Warheads
- Less-Than-Lethal Weapons

RF Effects and Hardening is a pervasive need driven by requirements at several different levels. The Operational Commands and Air Logistic Centers (ALCs) have articulated their user level needs for RF Effects Systems Survivability. The Phillips Lab is the prime executor of high power RF effects and Hardening programs, and, as required, supports customers in more general EMI/EMC efforts. In addition, MAJCOMs and other users have long term needs which include:

- Agent Defeat Technology
- Space Debris Simulation

Finally, the RF Weapons (Thrust 4) and Space Control Technologies (Thrust 5) are interlinked. AFSPC has a strong need for Thrust 4 RF effects and hardening technologies for protection of satellites and SATCOM ground-link equipment. Thrust 5 is also dependent on Thrust 4 for HPM source technology.

GOALS

The overall goals of the RF Weapons thrust are to develop and transition RF weapons technology into the operational inventory, and to protect US systems against the expanding threat represented by similar foreign systems. The Weapons portions of this thrust is organized under four Mission Application programs which perform research in response to user needs. These programs will provide revolutionary rather than incremental advances in friendly force capabilities.

- HPM Aircraft Self Protection (ASP)
  - Counter Surface-to-Air & Air-to-Air Missile
  - Large Aircraft IR Countermeasures
- HPM Suppress Enemy Air Defenses (SEAD)
- HPM Command Control Warfare/Information Warfare (CCW)
  - Air Interdiction of C^4I Assets
  - Degrade Enemy Air Control
  - Degrade Enemy Military Base Operation
  - Hardened Target Weapons
- RF Active Denial Technology (ADT)
  - Less-Than-Lethal Weapons
- The RF Effects and Hardening programs are organized into many overlapping technology efforts which includes

- RF Environments & System Responses
- RF Test & Measurement Techniques
- RF Protection Techniques
- RF Standards, Handbooks, & Design Guides
- Hardness Maintenance/Hardness Assurance
- Planning & Execution of Systems Level Tests

The result is a fully integrated approach to RF Systems Effects, Vulnerability, and Lethality, covering natural, inadvertent man-made, and potential hostile RF weapons threats.

Enabling Technologies are pursuing long range goals in conducting a number of exploratory research programs.

- Solid Liner Implosions
  - Agent Defeat Warhead Technology
  - Space Debris Simulation
  - Micro Fission/Micro Fusion Technology
- High Power/Fast Switch Testbed
  - Ultra High Pulse Power Drivers
  - Very Fast Acting, High Power Switches
  - Long Range, Second Generation RF Weapons

CHANGES FROM LAST YEAR

RF Weapons was reorganized during FY 93 from basic technology subthrusts to an integrated approach focusing on specific military applications. This realignment reflected the increasing maturity of RF weapons technology and the potential for near-term RF weapons meeting high priority User Needs. FY96 has witnessed further evolutionary changes to include-

<u>HPM Suppress Enemy Air Defenses (SEAD):</u> HPM SEAD has considerably accelerated in pace with the award of a hardware development contract. This effort will lead to the fabrication of two brassboard prototypes for field demonstration in FY99 - with an

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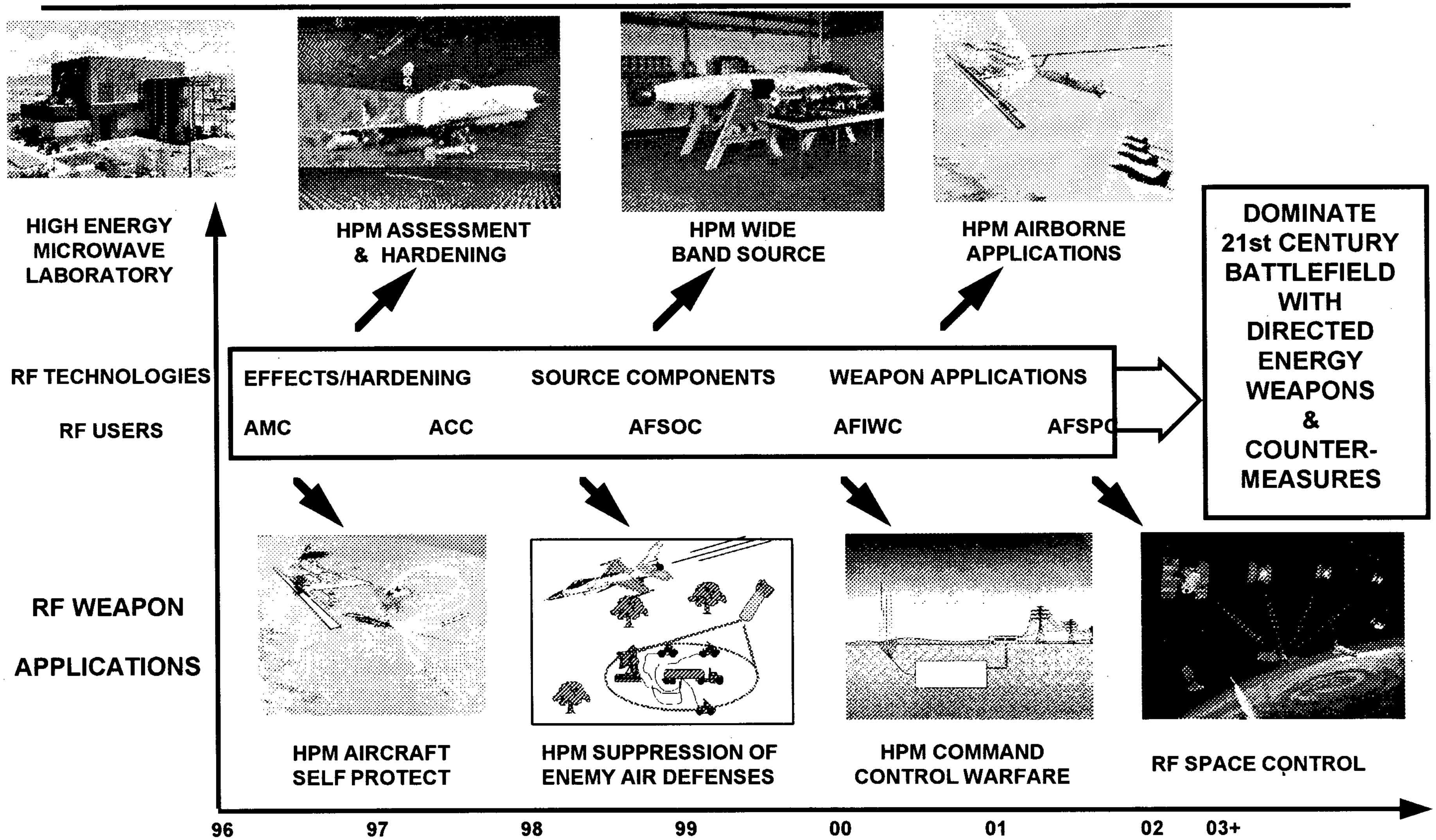
RF WEAPONS



anticipation of a second generation hardware effort leading to further field demonstrations in FY02+.

HPM Command Control Warfare (CCW): HPM CCW has continued to grow in consonance with the increased emphasis on Information Warfare by the Air Force and Joint Staff. The program has been redesignated C^2W/IW, and these increased efforts have led to creation of an RF effects laboratory specifically for C^3 subsystems.

HPM Counter Air (CA): Reductions in available Thrust 4 Exploratory Development funding has necessitated suspension of the HPM CA program. Selected technologies supporting HPM C^2W/IW & SEAD, however, are being continued with these latter programs' sponsorship.

Enabling Technology has been descoped and combined with the RF Sources Subthrust. Emphasis in this area is now directed primarily at ultra high, fast switch technology in support of second generation HPM sources.

MAJOR ACCOMPLISHMENTS

HPM Sources are the key to successful RF Weapons Applications, and have made major progress. Some notable achievements during FY96 have been:

- The narrow-band compact MILO demonstrated a 50% increase in output power and threefold increase in pulse-length.
- The wide-band H-3 source has reduced pulse rise time by over 60% while maintaining the same output power as the predecessor H-2. Construction of the H-4 has been initiated.
- GaAs switches operating at 100 kV and compact stacked transmission lines have been developed in support of the GEMII wide-band source. These technologies will enable major improvements in potential compact, steerable UWB sources for a number of applications.
- HPM Source subsystem designs have also been transitioned into successful hardware.
- The Impulse Radiating Antenna has been fabricated in four meter and 18 inch designs. These antennas have demonstrated efficient, compact, very high-gain wide-band operation.
- The Coaxial Beam Rotating Antenna (COBRA) is in development. This high-gain design will convert "hole-in-the-donut" TM-like to TE-like output with max E-field intensity on boresight.
- Explosively driven MCG and MHD pulse power systems have also been transitioned from the laboratory to experiments in the field.

RF Effects programs have also continued to undergo major growth during FY96.

- The RF Effects database on potential target threat missiles, IADS, and C^3 systems, as well as materials, buildings and structures has continued to expand.
- Phillips Lab has created a RF Effects laboratory specifically dedicated to the testing of command, control, and communications electronics subsystems.
- The Phillips Lab ELLIPTICUS antenna and personnel are supporting RF effects evaluations of the B-2 at Palmdale.

Finally, Phillips Lab has been the focal point in many NATO joint and bilateral efforts. This has resulted in data exchanges, cooperative test projects, and improved interoperability of US and NATO assets. PL has also been a major player in dual-use transitioning of RF Effects and Hardening technologies with the FAA and Industry.

MILESTONES

The technology activities of the RF Weapons Thrust are converging on several mission applications culminating in a series of CEs and ATDs during the next five years. The most critical program milestones are associated with generating the RF effects requirements database, demonstrating candidate HPM sources, and integrating the down-selected systems into practical packages for the mission applications. Although the Metrics associated with these milestones are classified, the calendar of major events are shown below:

Mission Application	Effects Complete	Source Demo	Systems CE/ATD
ADT	FY96	FY96	FY96
ASP	FY96	FY96	FY98
SEAD	FY97	FY97	FY99
C^2W/IW	FY98	FY99	FY00

THRUST 5: SPACE CONTROL TECHNOLOGIES

USER NEEDS

AFSPC Space Control requirements are taken from the Space Surveillance, Counterspace, and Missile Defense Mission Area Plans (MAPs). Together, these three MAPs define the Space Control Mission Area requirements. SMC requirements derive directly from the AFSPC Space Control MAPs. Additional insight into the Product Center requirements has been obtained through contacts with individual System Program Offices and through the Technical Planning Integrated Product Team (TPIPT) Technology Development Planning process that supports the MAPs. Space Control technology needs fall into the following categories:

Space Surveillance:
- Technology to detect, identify, and assess space objects (debris and spacecraft)
- Improved launch detection technologies
- Mission payload assessment technology
- Technology for anomaly resolution

Counterspace Protection:
- Attack and Fault Detection Sensors
- Emergency Communications
- Advanced computing technologies
- Natural and threat environment protection of EO and RF systems
- Survivable Optics
- Active Protection Technologies
- SATCOM Terminal Hardening

Counterspace Negation:
- RF Susceptibility Research
- RF Source Component Technologies
- Vulnerability Assessment Technology
- Command and Control Warfare

Missile Defense:
- Decision Support Systems
- Enhanced Data Fusion Technology
- Survivability techniques
- Lasers in space

GOALS

Technology developments are needed in each of the Space Control mission areas. PL/WS is advancing technologies to improve operational force capabilities to maximize situation awareness, to accelerate the decision and tasking process, to protect US and Allied space systems, and to take required negation action against enemy assets. An integrated research approach is planned to provide the required levels of technology development effort in each area so that operational forces have balance across all Space Control missions. Specific technology goals are:

Space Surveillance: Evaluate multi/hyper-spectral, thermal, radiometric sensor technologies for space applications; develop parallel processing technologies for real-time image analysis; develop high-resolution, ground-based optical imaging technology and signature data collection capabilities for detailed threat assessments; develop advanced intelligence data analysis technologies for spacecraft sensor data fusion and identify advanced methods to exploit all-source intelligence data; develop simulation and display technologies for realistic training and exercise support for operators.

Counterspace Protection: Develop threat warning and attack reporting architecture and enabling technologies; develop techniques to make materials capable of withstanding the effects of electromagnetic, and other advanced weapon attacks, and the natural debris environment in space; develop technology solutions that help prevent enemy use of US space systems; develop advanced all-threat satellite response modeling and assessment capability; identify, evaluate, demonstrate and transition high-data rate, survivable communications technologies; and develop near real-time DEW deconfliction technologies.

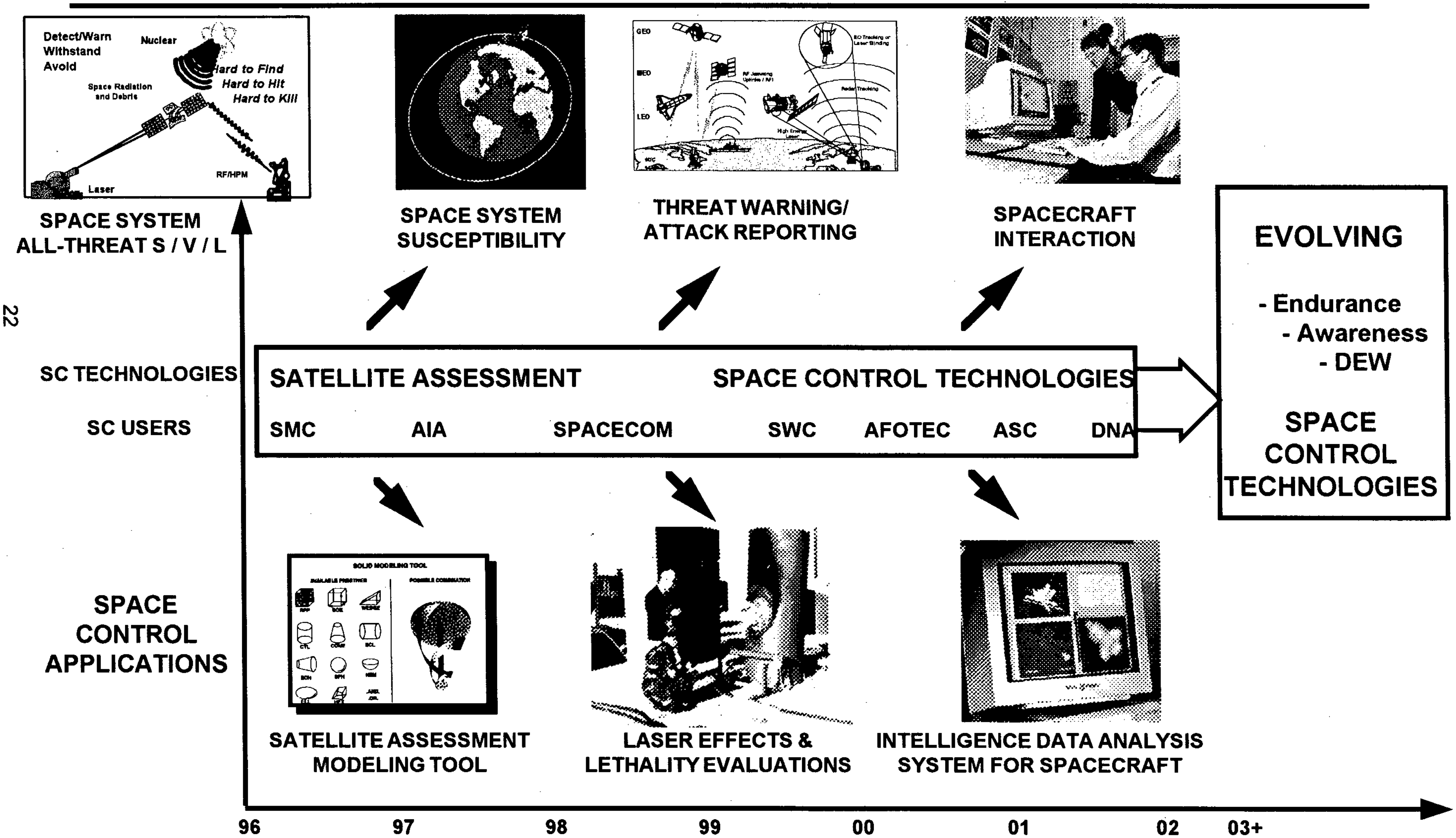
Counterspace Negation: Develop directed energy (laser and high-power microwave) component technologies that will deliver both temporary and permanent effects against space, ground, and user segments of a satellite network, or for command and control warfare; develop technologies that will support analysis of kinetic energy weapon (KEW) capabilities against hardened, ground-based network control nodes; develop mature directed-energy weapon predictive codes; define and develop battle damage assessment (BDA) technologies for domestic and foreign space systems to facilitate decision making support.

Missile Defense: Quantitatively assess the effectiveness of KE weapons against missile borne weapons of mass destruction; develop technologies for sensor data fusion and image simulation; develop simulation and display technologies for training and exercise support; enhance and apply all-threat modeling; develop BDA technologies for assessments and rapid decision support.

MAJOR ACCOMPLISHMENTS

Notable progress was made in many of the Space Control Technology areas during FY96.

DIRECTED ENERGY
SPACE CONTROL TECHNOLOGIES



Several analysis tools were developed along with parallel processing implementation of existing codes for vulnerability, susceptibility, and survivability assessments on space systems. Advances in laser vulnerability assessment made possible by the development of new material properties simulation tools are directly aiding technology development in the GBL and ABL programs. Considerable progress was made in meeting Intelligence Data Analysis System for Spacecraft (IDASS) Advanced Technology Demonstration milestone goals. Device hardening experiments were completed on several optical and infrared satellite sensor arrays. Similar experiments on satellite receivers are helping to define technology development requirements in both HPM sources and in satellite hardening and protection devices.

FY96 Space Control Protection activities included the following: Coordination with AF and US Space Command users/operators to establish threat warning/attack reporting architectures consistent with evolving DEW threat projections. Building on preliminary Threat Warning/Attack Reporting concept definition studies conducted in FY95, efforts were initiated to develop a low-level RF interference receiver (detector and antenna configuration) for eventual space demonstration. Preliminary experimental investigations were begun of the utility of microbolometer technologies for pulsed/CW laser detection. Experiments were conducted to determine the individual and combined effects of space radiation (proton environment) and RF illumination on the performance characteristics of candidate CCD detectors for space-based surveillance sensors. Functional performance of the radiation-degraded detectors in an optical telescope/camera configuration under RF illumination has been demonstrated to evaluate potential protection techniques. Extensive data from experiments and analyses on the performance of optical materials in radiation and laser environments has been consolidated in an interactive electronic format. Also the enhanced radiation, stressed-environment performance characteristics of various critical satellite sensor, attitude reference, and communication subsystems were determined.

The RF Space Control Applications program developed a PC version of its Predictive RF Effects Coupling Tool (PRFECT). Capability to statistically model the range/elevation sensitivity of a threat source's gain was added to the analysis tool. An HPM Primer was published that provides a program manager with an understandable overview of HPM technologies and how they can be applied to the Space Control mission. New survivability experimental techniques were applied to several satellite subsystems and components. This data is crucial to help define HPM source and hardening technologies for space applications.

The Satellite Assessment Center's FY96 laser effects testing activities included conducting the first ever series of susceptibility experiments on foreign CCD arrays using an out-of-band CW laser. These were performed to quantify deny-degrade-disrupt-destroy (D^4) effects. In addition, an extensive test series was completed to quantify temperature dependent coupling on all classes of Aerospace materials. These measurements, when incorporated into vulnerability assessment codes, provide high confidence in satellite vulnerability estimates. The laser effects testing activities also matured optical modeling technology to support the ABL and the US Space Command laser clearinghouse on near real-time predictive avoidance.

Development of the Phase I IDASS system was completed and demonstrated for program customers. The Phase I development system was also installed at the US Space Command for operational testing and feedback to the development team.

CHANGES FROM LAST YEAR

The technology developments described above are in place to support the Space Control mission area and they will remain almost unchanged throughout FY97. The only change is that we will discontinue the mission payload assessments effort soon after completion of the SICIM demonstration.

MILESTONES

<u>Space Surveillance:</u>
- SICIM Demo (4QFY96)
- IDASS Demo (4QFY98)

<u>Counterspace Protection:</u>
- Operational DAW System (1QFY97)
- Microbolometer TW/AR Laser Detector Brassboard (4QFY98)
- Advanced RF Threat Warning Space Demonstration (2QFY01)Revise spacecraft laser vulnerability criteria for US Space Command Laser Clearinghouse Program (1QFY97)

<u>Counterspace Negation:</u>
- Prototype HPM System (4QFY00)
- RF Assessment Capability Algorithms: Integration and Validation (4QFY97)
- Incorporate physics for deny-degrade-disrupt-destroy prediction: System effects and validation (4QFY97)

<u>Counterspace Protection:</u>
- Intelligence Data Analysis System for Space craft Demo (4QFY98)

GLOSSARY

A

ABL	Airborne Laser
ACC	Air Combat Command
ADONIS	AMOS Daytime Optical Near-Infrared Imaging System
AEOS	Advanced Electro-Optical System
ADT	Active Denial Technology
AFAE	Air Force Acquisition Executive
AFMC	Air Force Materiel Command
AFMC/ST	Director of Science and Technology
AFOSR	Air Force Office of Scientific Research
AFSOC	Air Force Special Operations Command
AFSPC	Air Force Space Command
AFTAC	Air Force Technical Applications Center
AL	Armstrong Laboratory
ALC	Air Logistics Center
AMC	Air Mobility Command
AMOS	AF Maui Optical Site
ASAT	Antisatellite
ASC	Aeronautical Systems Center
ASP	Aircraft Self Protection
ATD	Advanced Technology Demonstration

B

BDA	Battle Damage Assessment
BMDO	Ballistic Missile Defense Organization
BMC^3I	Battle Management Command, Control, Communications, and Intelligence

C

CA	Counter Air
CCW	Command and Control Warfare
COIL	Chemical Oxygen-Iodine Laser
COPUOS	Committee on Peaceful Uses of Outer Space
CRDA	Cooperative Research and Development Agreement
C3I	Command, Control, Communications, and Intelligence

D

D4	Deny, Disrupt, Degrade, Destroy
DEW	Directed Energy Weapon
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
DPL	Diode-Pumped Laser
DSP	Defense Support Program

E

EM	Electromagnetic
EMP	Electromagnetic Pulse
ESC	Electronics System Center

F

FAA	Federal Aviation Administration
FTA	Focused Technology Area

G

GaAs	Gallium-Arsenide
GBL	Ground-Based Laser
GEO	Geosynchronous
GHz	GigaHertz
GW	GigaWatt

H

HEML	High Energy Microwave Laboratory
HPM	High Power Microwave
HSC	Human Systems Center
Hz	Hertz

I

IDASS	Intelligence Data Analysis System for Spacecraft
IR	Infrared
IRCM	Infrared Countermeasures
IR&D	Independent Research & Development

J

JDL	Joint Directors of Laboratories
JPL	Jet Propulsion Laboratory

K

km	kilometers
kW	kiloWatts
kHz	kiloHertz

L

LANL	Los Alamos National Laboratory
LANTIRN	Low Altitude Navigational and Targeting Infrared for Night
LEO	Low Earth Orbit
LESLI	Large Electromagnetic System Level Illuminator
LLNL	Lawrence Livermore National Laboratory
LIME	Laser Induced Microwave Emission
LPD	Low Probability of Detection
LPI	Low Probability of Intercept

M

m	meter
mW	milliWatt
Malabar	PL Optical Facility in Melbourne, Florida
MAP	Mission Area Plan
MOA	Memoranda of Agreement
MOPA	Master-Oscillator Power-Amplifier
MOU	Memoranda of Understanding
MPA	Mission Payload Assessment
MSTRS	Miniaturized Satellite Tracking and Reporting System
MW	MegaWatt

N

NASA	National Aeronautics & Space Administration
NATO	North Atlantic Treaty Organization
NLO	Nonlinear Optics

O

OSD	Office of the Secretary of Defense

P

PACE	Point-Ahead Compensation Experiment
PILOT	Phased Integrated Laser Optics Technology
PL	Phillips Laboratory
PMD	Program Management Directive

R

R&D	Research & Development
RF	Radio Frequency
RL	Rome Laboratory

S

S&T	Science & Technology
SBIR	Small Business Innovative Research
SEAD	Suppression of Enemy Air Defenses
SHIVA STAR	Free world's most powerful fast capacitor bank
SIE	Satellite Imaging Experiment
SMC	Space & Missile Systems Center
SNL	Sandia National Laboratory
SOI	Space Object Identification
SOR	Starfire Optical Range
SPO	System Program Office
S/V/L	Survivability/Vulnerability/ Lethality
SWC	Space Warfare Center

T

TAP	Technology Area Plan
TEO	Technology Executive Officer
TMD	Theater Missile Defense
TPDEW	Technology Panel for Directed Energy Weapons
TPIPT	Technology Planning Integrated Product Team
TW/AR	Threat Warning/Attack Reporting

U

USSPC	US Space Command

W

WarSim	Warfare Simulations
WL	Wright Laboratory

Technology Master Process Overview

Part of the Air Force Materiel Command's (AFMC) mission deals with maintaining technological superiority for the United States Air Force by:

- Discovering and developing leading edge technologies
- Transitioning mature technologies to system developers and maintainers
- Inserting fully developed technologies into our weapon systems and supporting infrastructure, and
- Transferring dual-use technologies to improve economic competitiveness

To ensure this mission is effectively accomplished in a disciplined, structured manner, AFMC has implemented the **Technology Master Process** (TMP). The TMP is AFMC's vehicle for planning and executing an end-to-end technology program on an annual basis.

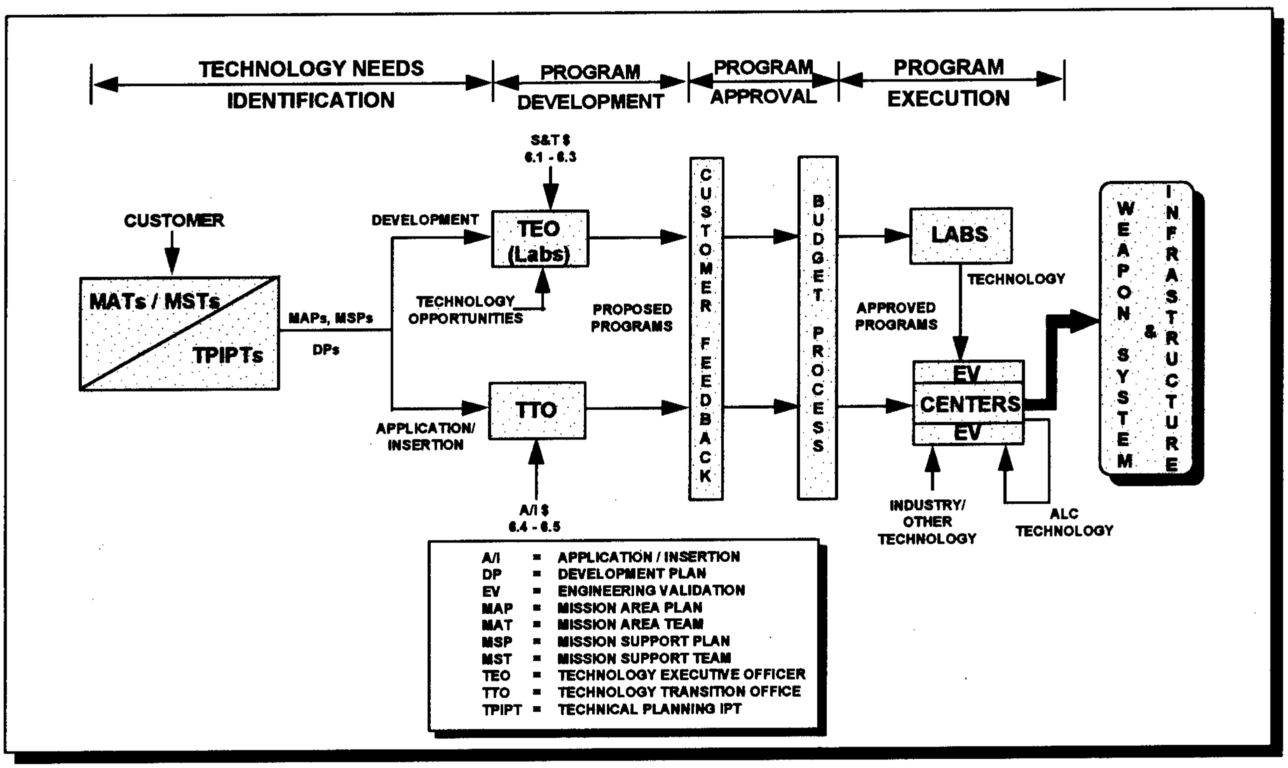


Figure 1 - Technology Master Process

The TMP has four distinct phases, as shown in Figure 1:

- Phase 1, **Technology Needs Identification** -- Collects customer-provided and customer-prioritized technology needs associated with both weapon systems, product groups and supporting infrastructure; then identify them by the need to develop new technology or apply/insert emerging or existing technology. These needs are derived in a strategies-to-task framework via the user-driven Modernization Planning Process.

- Phase 2, **Program Development** -- Formulates a portfolio of dollar constrained projects to meet customer-identified needs from Phase 1. The Technology Executive Officer (TEO), with the laboratories, develops a set of projects for those needs requiring development of new technology, while the Technology Transition Office (TTO) orchestrates the development of a project portfolio for those needs which can be met by the application/insertion of emerging or existing technology.

- Phase 3, **Program Approval** -- Reviews the proposed project portfolio with the customer and obtains approval for the portfolio through the budgeting process. The output of Phase 3 is the authorizations and appropriations required, by the laboratories and application/insertion programs, to execute their technology projects

- Phase 4, **Program Execution** -- Executes the approved S&T program and technology application/insertion program within the constraints of the Congressional budget and budget direction from higher headquarters. The products of Phase 4 are validated technologies that satisfy customer weapon system and infrastructure deficiencies.

Additional Information

Additional information on the Technology Master Process is available from HQ AFMC/STR, DSN 787-6777/8764, (513)257-6777/8764.

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